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Spectral Detection of the Defect of Short Circuit in a Permanent Magnets Synchronous Machine

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Abstract: The work suggested in this research consists of the detection of a three-phase short circuit in a synchronous permanent magnets machine supplied with a three levels inverter of voltage PWM, by the means of the spectral analysis of the stator currents. The practice showed that at the time of a short circuit it is primarily the stator resistance which considerably will increase. For that we establish the model of the operational engine first of all. Then we will give the model of the engine weakening and will treat the results of simulation for finally comparing the spectra of harmonics of the currents of the two models. The early knowledge of such a defect starting from a simple spectrogram makes it possible to avoid the total dysfunction of the machine.

Key words: Inverter of voltage PWM on three levels, synchronous machine with permanent magnets, defect of short circuit, spectra analyzes, power spectral density, torque and stator current oscillations

INTRODUCTION

The technological developments allowed the electric machines, in particular synchronous one, to find the flexibility of control and the dynamic performances naturally obtained with the machine with continuous current (Boucherit, 1995; Bose, 1986) in addition with the development of new material, like the permanent magnets containing rare earth, these synchronous machines present many advantages compared to the other machines, a weak inertia and a raised mass couple, unfortunately, these machines as all the others are prone to considerable malfunctions in particular the short-circuits.

The defects which appear in the electric machines have varied causes: they can be due to the ageing of the components of the engine or to the conditions of use or quite simply to a manufacturing defect of which the effect would be unperceivable at the time of the startup. In order to avoid spurious shutdowns, and with the development of sensors of monitoring and detection of breakdown, it is possible to diagnose various types of defects and to cure it.

The purpose of this study is the detection of a three-phase short circuit in a synchronous permanent magnets machine supplied with a three levels inverter of voltage PWM, by the means of the spectral analysis of the stator currents, to avoid the total dysfunction of the machine.

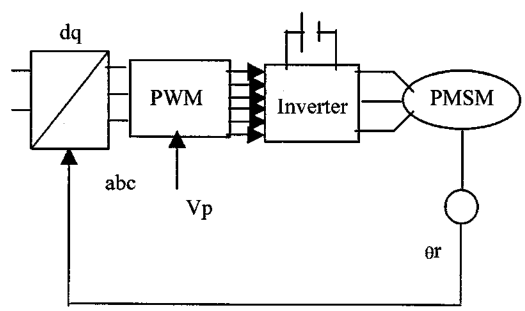

Fig. 1: Association of a PWM inverter with a PMSM

The general scheme of present study is given on Fig. 1, it is constituted of a three levels PWM inverter which supply a permanent magnets synchronous machine with salient poles.

Inverter of voltage on three levels: Our machine is supplied with a three levels three-phase inverter PWM, whose general diagram is showed on Fig. 2 (Berkoukk, 1995).

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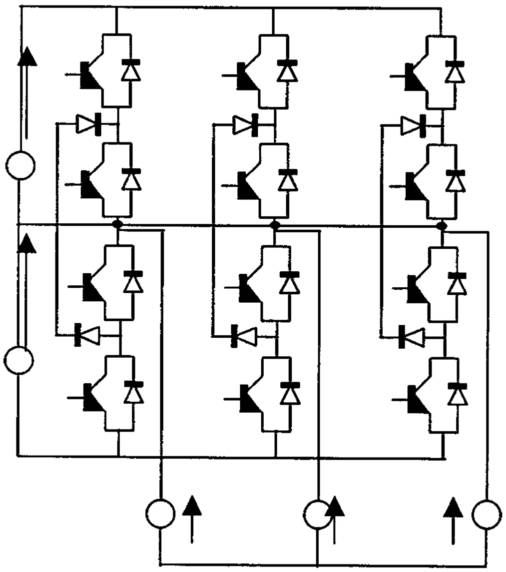

Fig. 2: General diagram of an inverter PWM on three levels

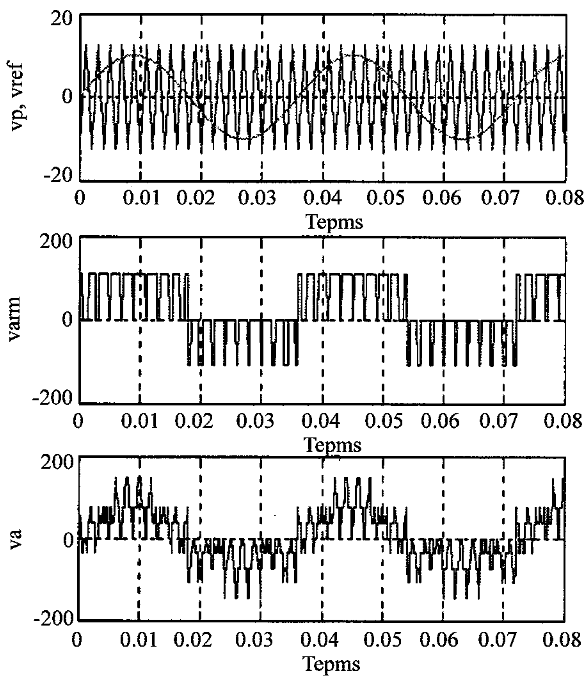

Fig. 3: Carrying reference, simple voltage and voltage of phase

The simple voltages are obtained (Fig. 3) starting from the following conditions:

If $(V_{réf} = V_p)$ and $(V_{réf} > 0) => V_K = + E/2$

If $(V_{réf} = V_p)$ and $(V_{réf} < 0) => V_K = -E/2$

If $V_{réf} = V_p => V_K = 0$

With

$V_{réf}$: Reference voltage standard;
V_p : Carrying;
V_K : Potential of the node K.

Model of the synchronous machine: The machine studied in this research is with salient poles, the model that we retained after transformation of Park is as follows:

$$\frac{dI_{ds}}{dt} = (V_{ds}-R_sI_{ds}+\omega_rL_{qs}I_{qs})/L_{ds}$$

$$\frac{dI_{qs}}{dt} = (V_{qs}-R_sI_{qs}-\omega_rL_{ds}I_{ds})/L_{qs}$$

$$\frac{d\omega_r}{dt} = p\left(C_{em} - C_r\right)/J$$

$$C_{em} = p\left(\phi_r + \left(L_{ds} - L_{qs}\right)I_{ds}\right)I_{qs}$$

With

R_s : Stator resistant
L_{ds} : Inductance of direct axis
L_{qs} : Inductance of quadratic axis
I_{ds} : Current of direct axis
I_{QS} : Current of quadratic axis
V_{ds} : Voltage of direct axis
V_{qs} : Voltage of quadratic axis
ω_r : Angular speed
Φ_r : Flow of permanent magnets
p : Number of pair of poles
C_{em} : Electromagnetic torque
C_r : Resistant torque
J : Inetia of the machine

The speed, the torque and the spectra energy of a stator current of the safe machine supplied with the three levels inverter are showed on the Fig. 4.

Study of the three-phase short circuit: The short circuits between phases appear in rollings up of different phases standard, in the case of a course three-phase circuit they are the three rolling up which is touched. It is primarily the stator resistance which will increase according to the number of whorls which will be short-circuited (Moreau, 1999).

Results analysis: The simulation has been done with Matlab software. Figure 4 presents angular speed, electromagnetic torque, and spectra of the current of the

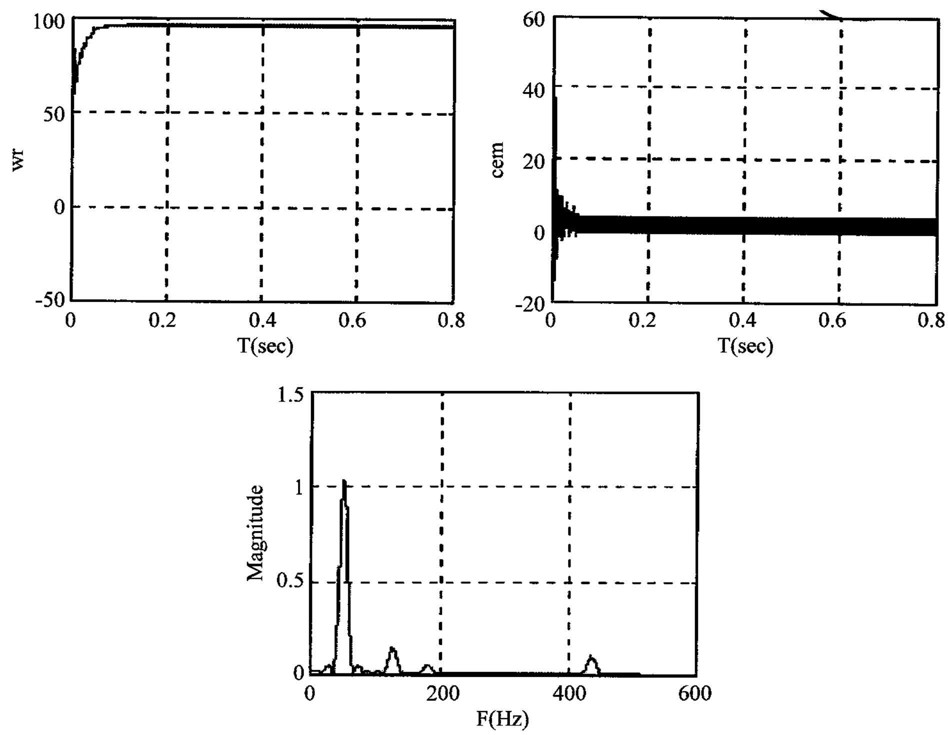

Fig. 4: Speed, electromagnetic torque and spectra energy of stator current in the safe motor

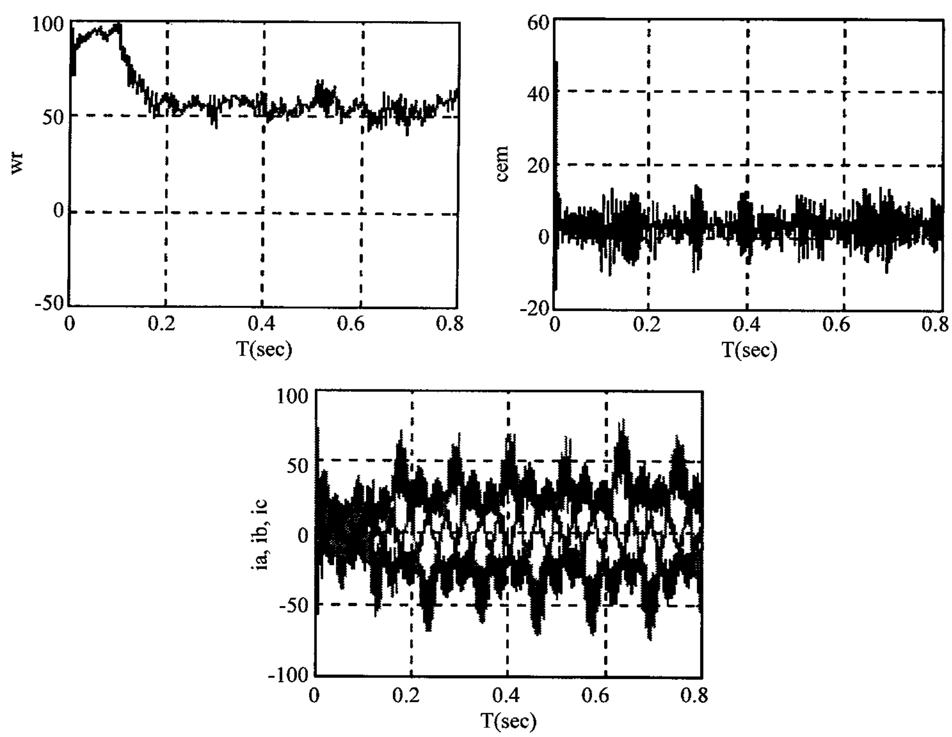

Fig. 5: Speed, torque and stator currents
Case of : 30% of short circuit in phase A, 10% in the phase B and 20% in the phase C

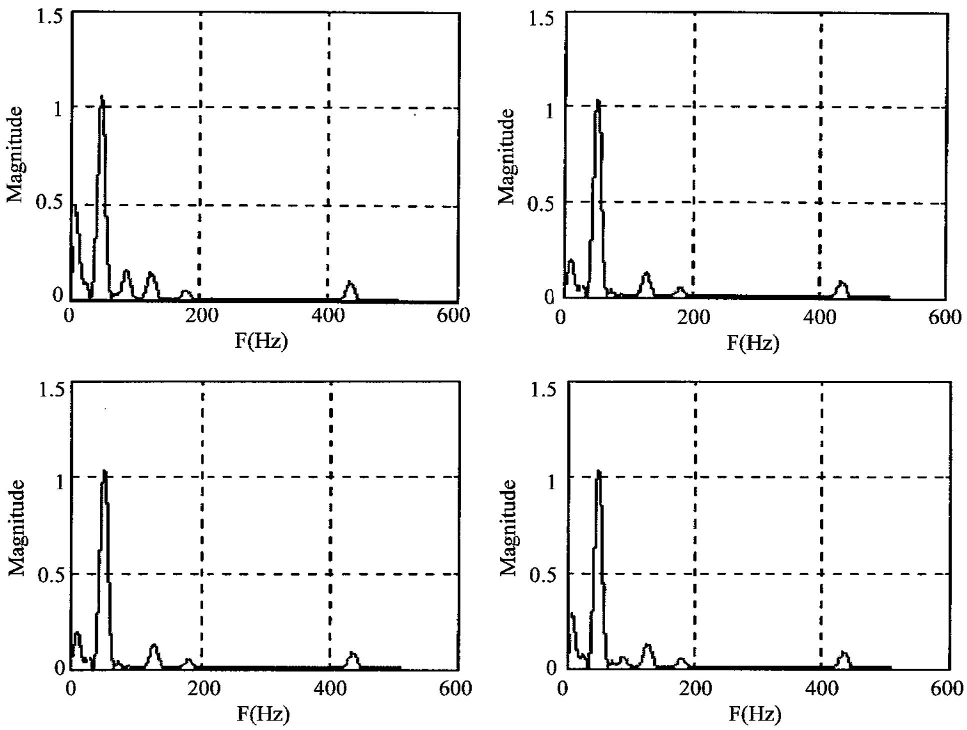

Fig. 6: Spectra energies of the stator currents

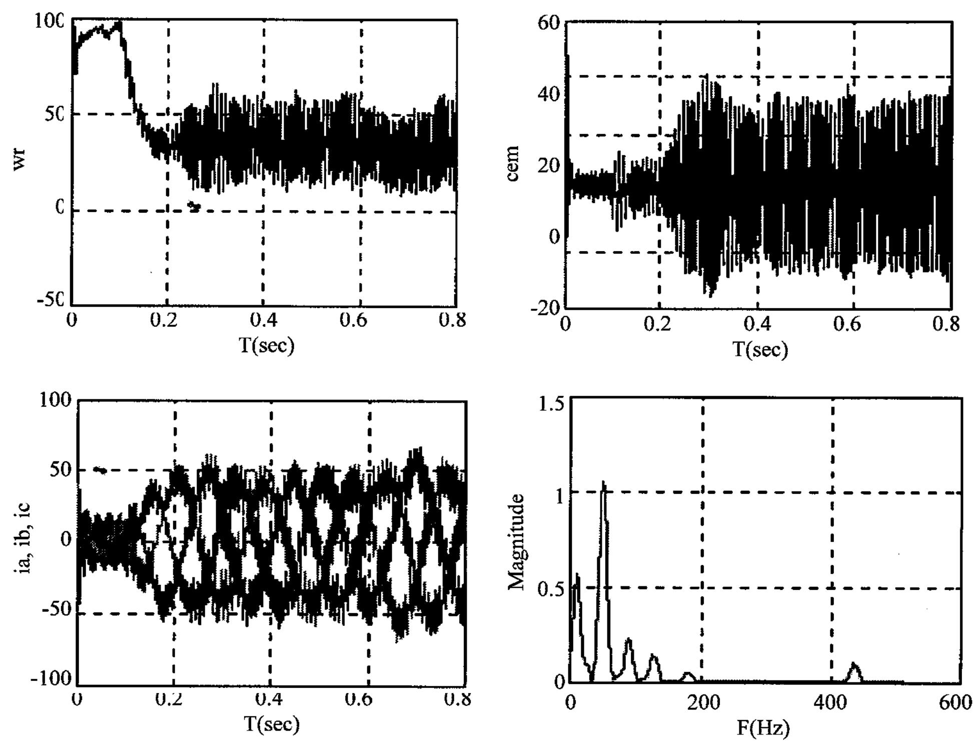

Fig. 7: Speed, torque, stator currents and spectra energy of the current
Case of 30% of short circuit in all the phases

safe machine we remark that the spectra shows the fundamental harmonic and few others due to the inverter.

Figure 5 shows speed torque and stator currents of phase A, B and C in the case of 30% of short circuit in phase A, 10% in the phase B and 20% in the phase C.

And theirs respective spectra are shown on Fig. 6, we note the apparition of new harmonics around the fundamental one their amplitudes are proportional to the defect. In Fig. 7 we present the case of 30% of short circuit in all the phases, the oscillations of both of speed, torque and currents have increased in relation to the last case. Speed is quantized in radian by second, torque by newton meter and currents by ampere.

CONCLUSIONS

A short circuit touchdown the three phases, would induce very strong currents which would lead to the fusion of the drivers, however, one short circuit near of the neutral generates an imbalance without causing the fusion of the drivers (Boumegoura, 2001).

The appearance of a short circuit in stator winding generates an increase in the stator currents and the appearance of other harmonics in the latter, the average electromagnetic torque of the machine remains constant, although it is disturbed, having oscillations proportional to the defect.

Speed has also oscillations around its permanent value, the latter decreases with the increase in the extent of the defect.

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